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Trieste, 20 November 2015

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Decadal predictability and prediction in a complex international context

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iCrea IC3 WCRP World Climate Research Programme SPECS Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

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What

Environmental forecasting

Why

Our strength …
- … research …
- … operations …
- … services …
- … high resolution …

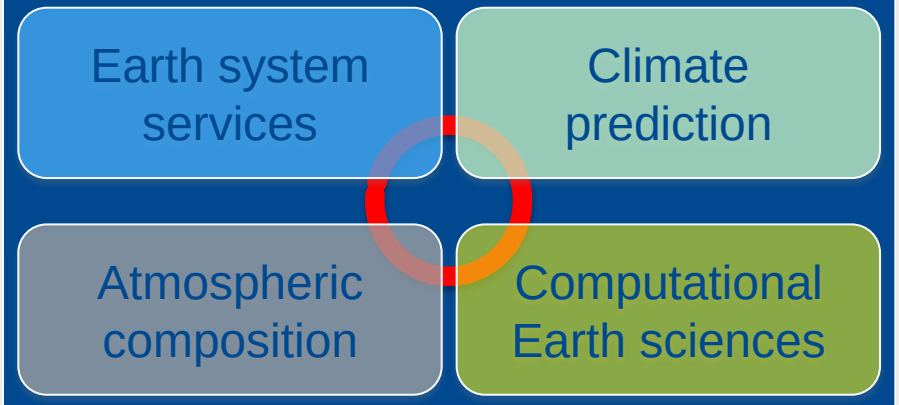
How

Develop a capability to model air quality processes from urban to global and the impacts on weather, health and ecosystems

Implement climate prediction system for subseasonal-to-decadal climate prediction

Develop user-oriented services that favour both technology transfer and adaptation

Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models



A part of the international ecosystem

WCRP and its core projects, particularly CLIVAR, have identified the need to advance the study of decadal climate variability and predictability (DCVP) and to continue experimental climate prediction.

WWRP Organization

S2S

PPP

JWGFVR

WCRP Organization

Joint Planning Staff

Data Advisory Council

Working Group

Seasonal to Interannual

CliC

CLIVAR

SPARC

Near-term climate prediction

Sea-Level Rise and Regional Impacts

Cryosphere in a Changing Climate

Changes in Water Availability

Clouds, Circulation and Climate Sensitivity

Climate Extremes

Cryosphere-Climate Interactions

Land-Atmosphere Interactions

Troposphere-Stratosphere

Panels

GSOP

RF

DCVP

IPCC

GFCS (Climate services)

CMIP

- DCPP (CMIP6)
- Drift and initial shock initiative

We are here

Very compartmental, need more promiscuity

Some of the CMIP5/AR5 lessons

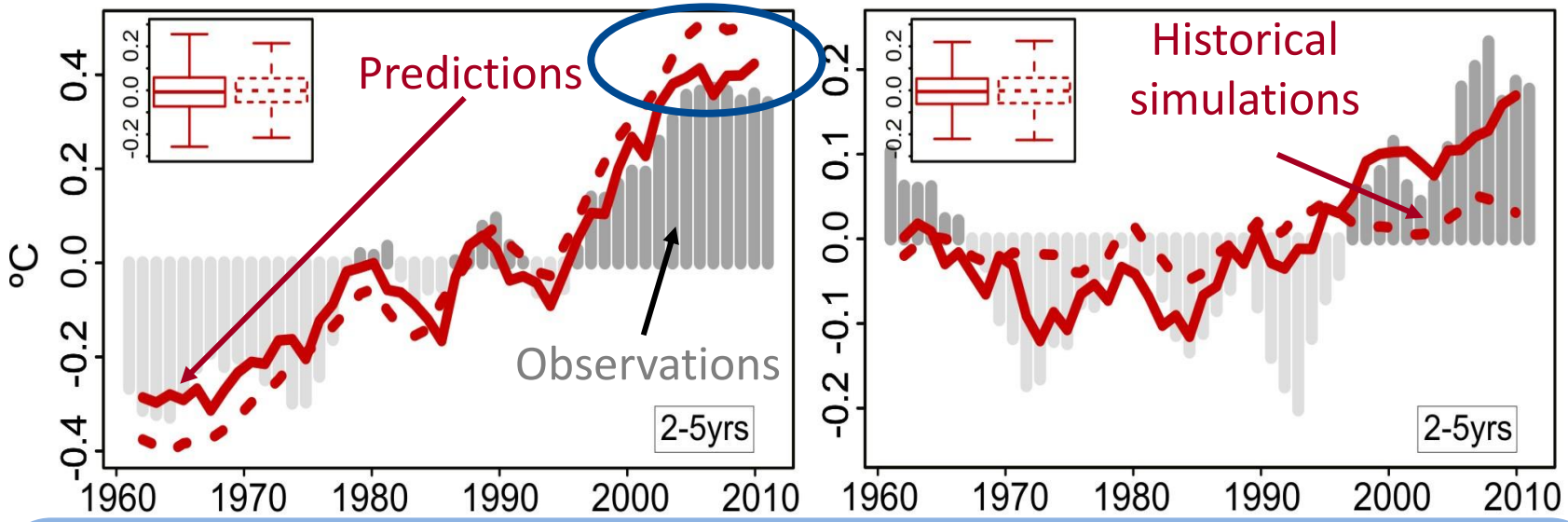
- The climate prediction and climate modelling community benefit from working closer together. But there is a language problem.
- Decadal prediction has skill.
- Most of the skill in temperature is forced by both natural and external forcings. However, forcings (e.g. volcanoes) have to be predicted too.
- Start the hindcasts every year.
- It is very important to use the same model configurations as for other climate experiments; learn about your model, use the hierarchy that is likely available.
- Drift, initial shock and systematic error are a hard reality we have to live with. Anomaly initialisation is not a solution yet. Why did not try more flux correction?

CMIP5 decadal predictions

CMIP5 decadal predictions. Global-mean near-surface air temperature and AMV against GHCN/ERSST3b for forecast years 2-5.

Global mean surface air temperature (GMST)

Atlantic multidecadal variability (AMV)



Initialised simulations reproduce the temperature tendencies and some of the AMV and suggest that initialization corrects the forced model response and phases in internal variability.

Doblas-Reyes et al. (2013, Nat. Comms.)

From the workshop introduction

Climate researchers were quick to propose and test various hypotheses for this "warming hiatus" but the verdict is still out as to its cause and to the failure of initialized coupled model predictions to detect it.

More on the forced model response

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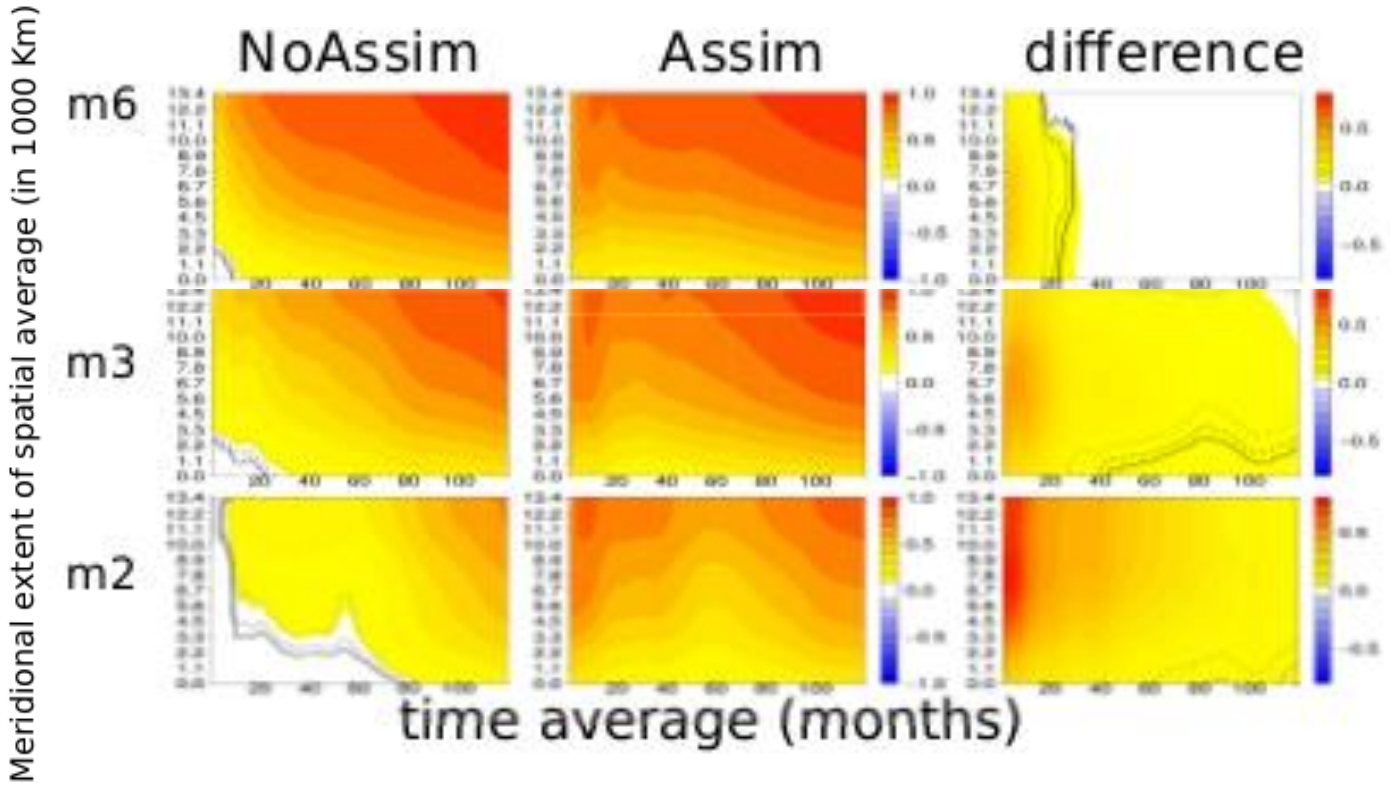
Correlation of the ensemble mean for DePreSys_PP air temperature.

(left) Assim, (centre) NoAssim and (right) their difference as a function of the integration along forecast time (horizontal) and space (vertical). Three versions ranked in decreasing order as a function of the slope of the linear trend of NoAssim.

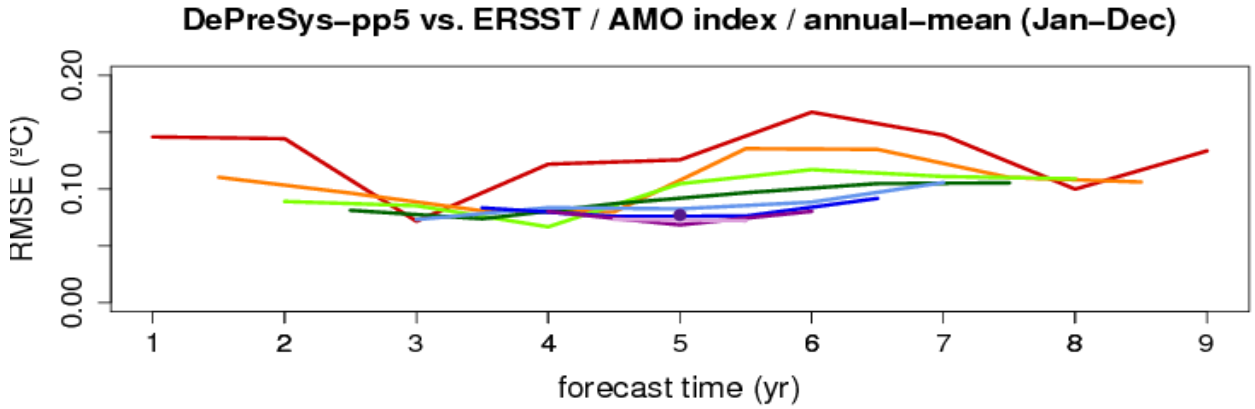
Hindcasts over 1960-2005 have been used and the reference dataset is NCEP R1. Black lines represent the confidence interval for the correlation differences.



Volpi et al. (2013, GRL)

Start the hindcasts every year

Annual-mean, ensemble-mean RMSE with respect to ERSST for the AMV index for DePreSys Assim with one start date every five years (top) and every year (bottom). Each colour shows the result for a different degree of averaging, from red (one year) to purple (nine years).



García-Serrano and Doblas-Reyes (2012, Clim. Dyn.)

CMIP5 decadal predictions

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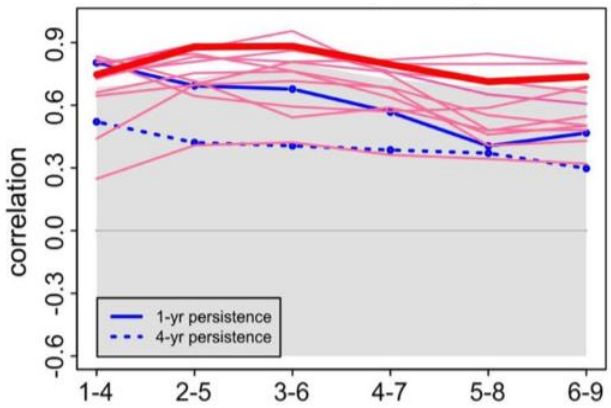
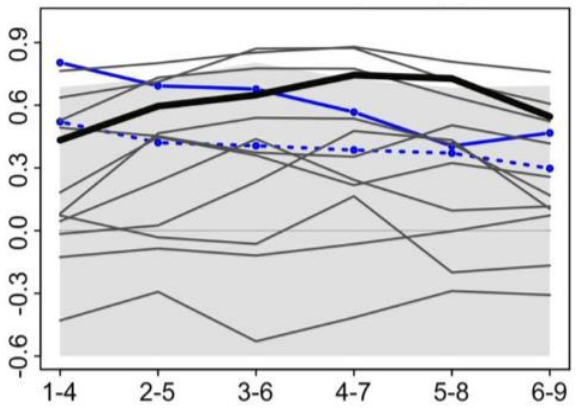
Correlation of the ensemble mean of the AMV against ERSST3b as a function of forecast time.

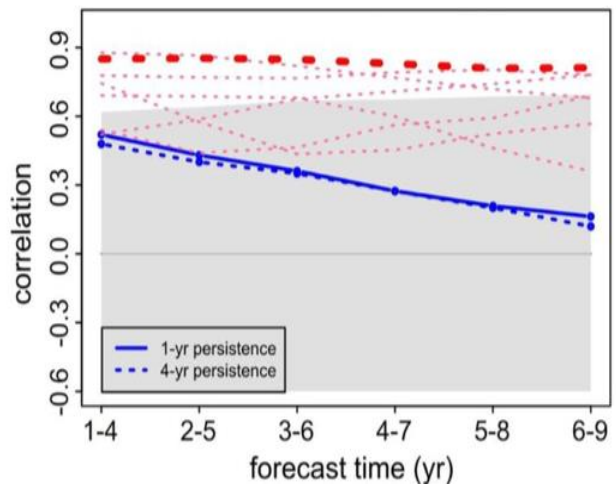
Init every 5 years



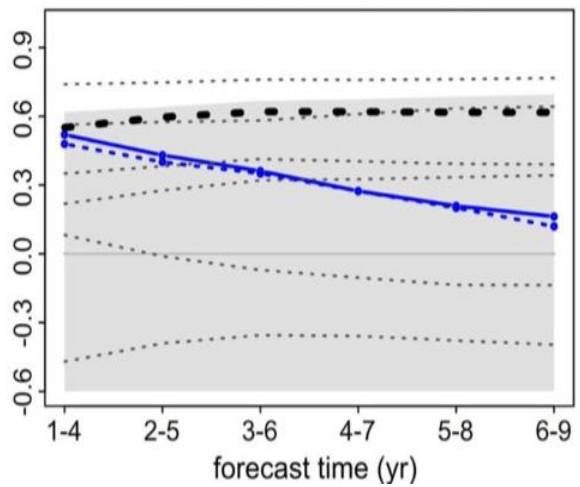
NoInit every 5 years



Init every year



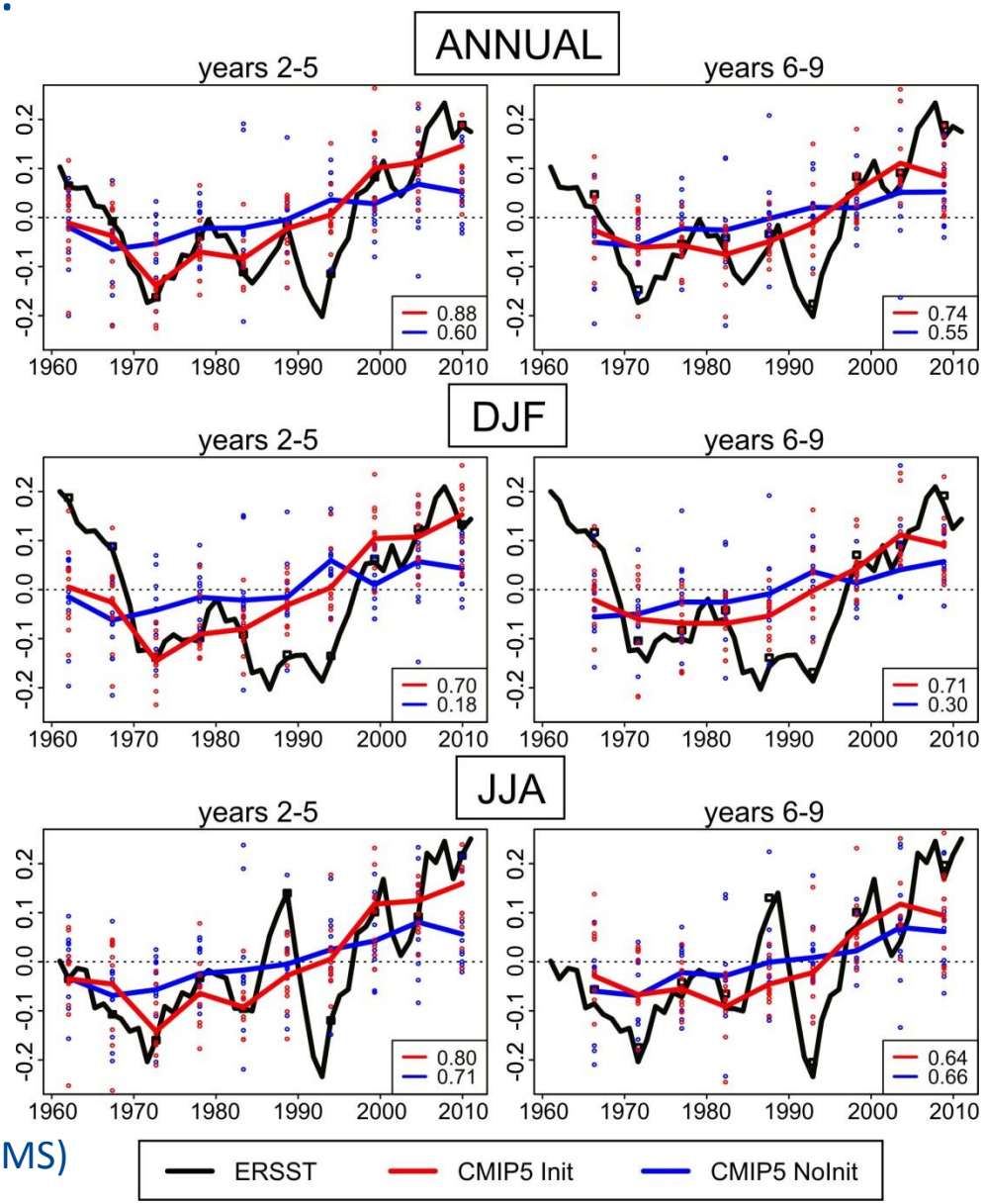
NoInit every year



García-Serrano et al. (2014, Clim. Dyn.)

CMIP5 decadal predictions

AMV time series.

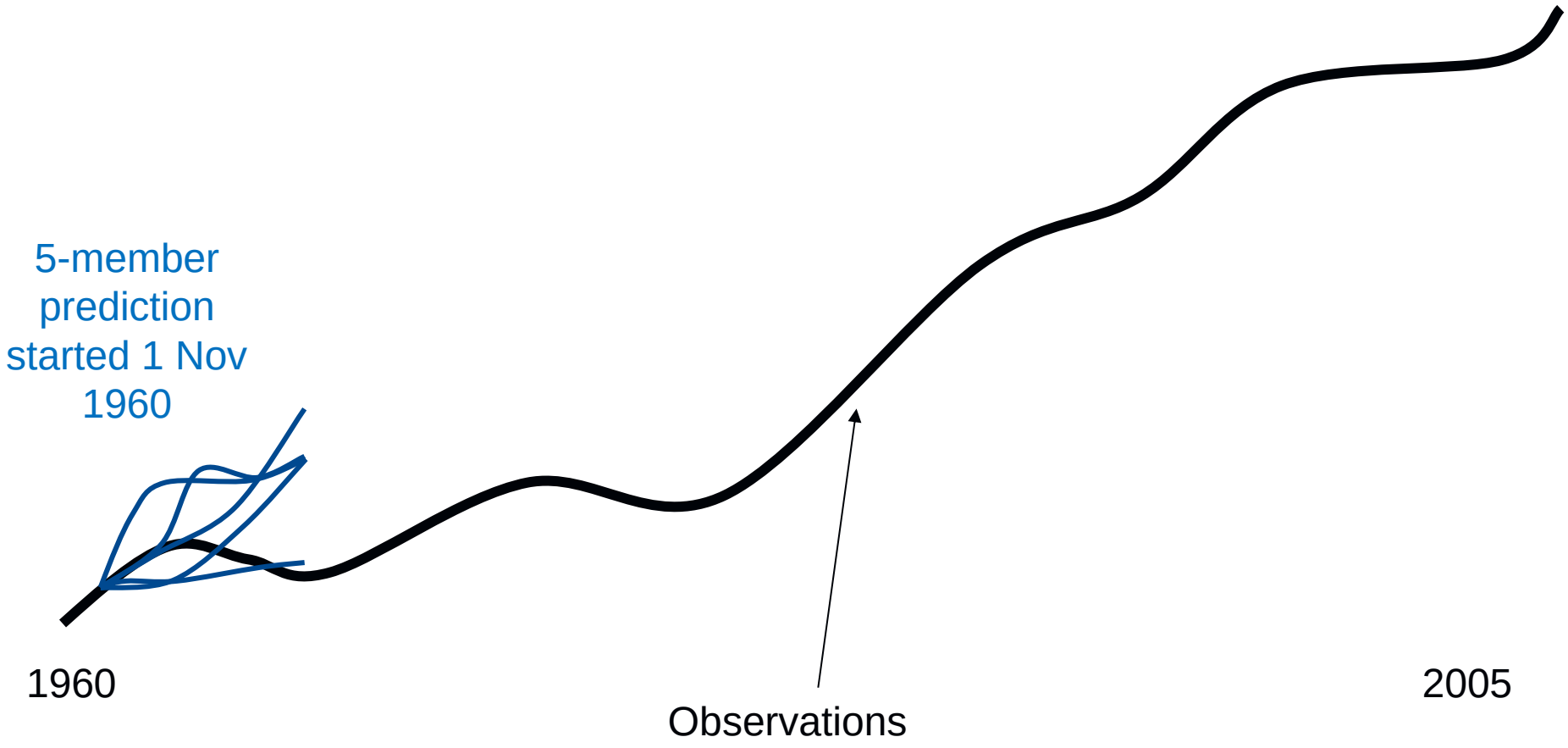


Guemas et al. (2014 , QJRMS)

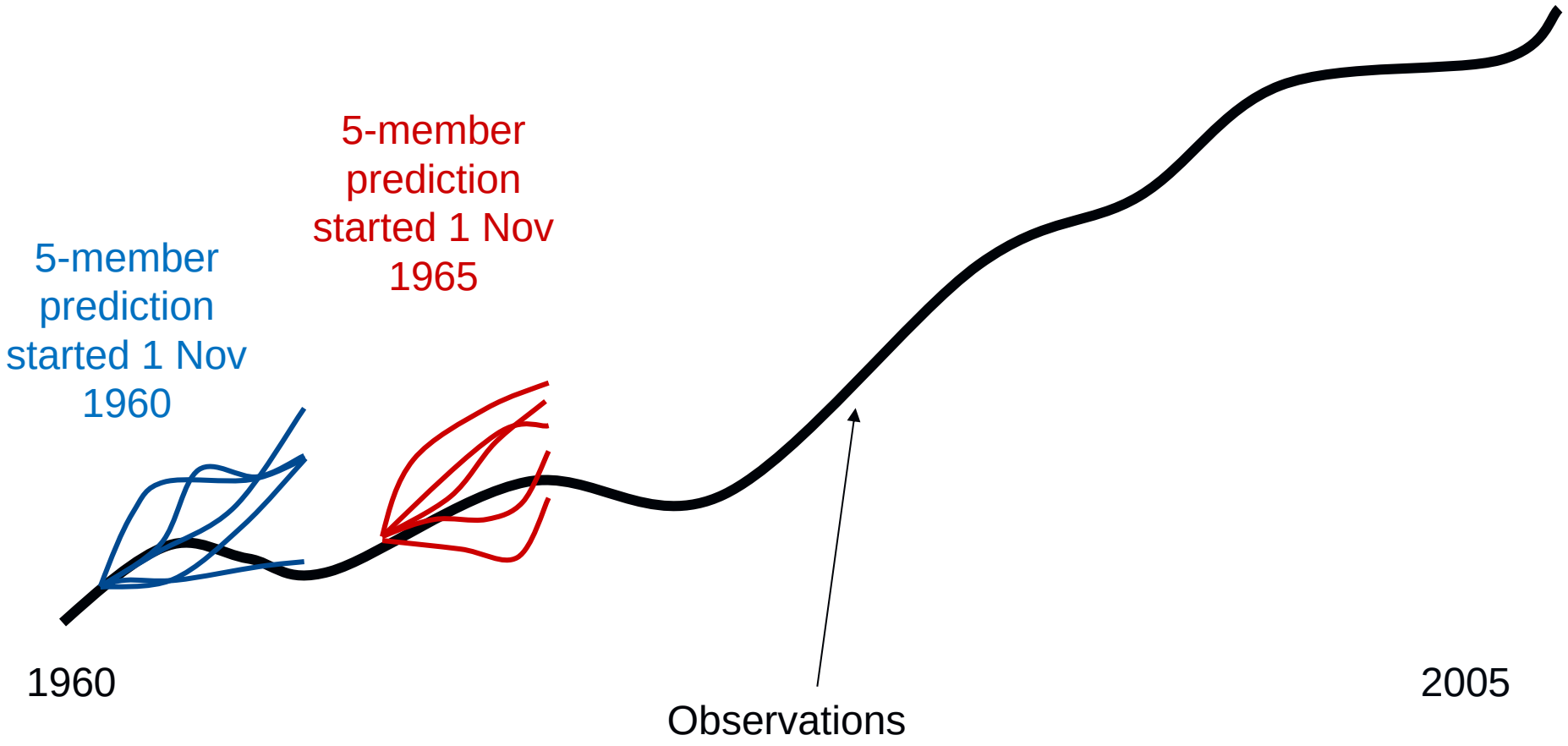
Initialising climate predictions

- Why initialising a climate model? To address the internal variability uncertainty source and make a skilful forecast, one of the requirements is an accurate knowledge of the initial state of the system.
- Steps to initialise an ensemble climate forecast system:
  - make the most of the available observations to rebuild the best estimate of the system state (reanalysis).
  - transfer such information to the model avoiding imbalances, i.e. initialise the climate prediction system
  - run the ensemble with initial perturbations to account for the initial-state uncertainty

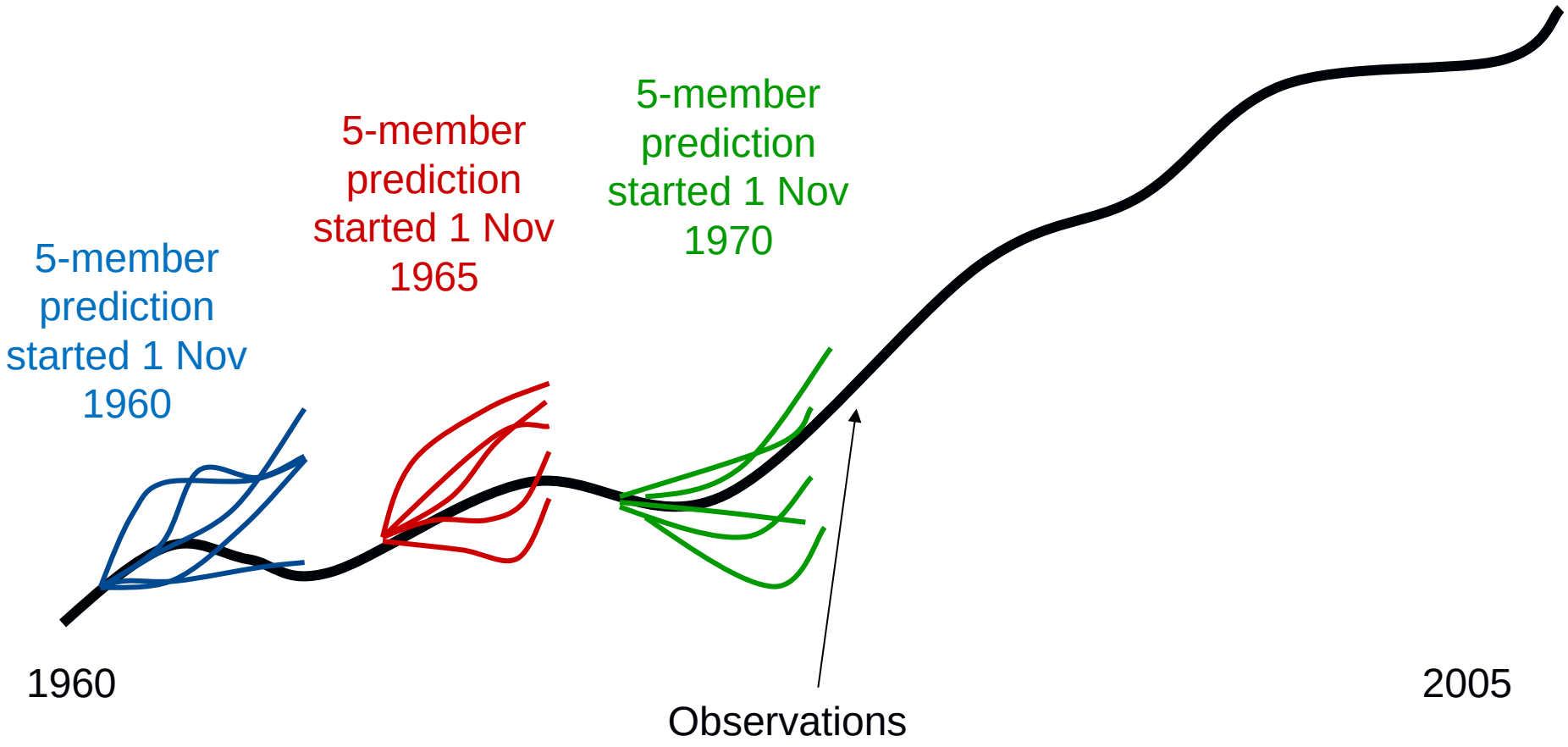
Climate predictions



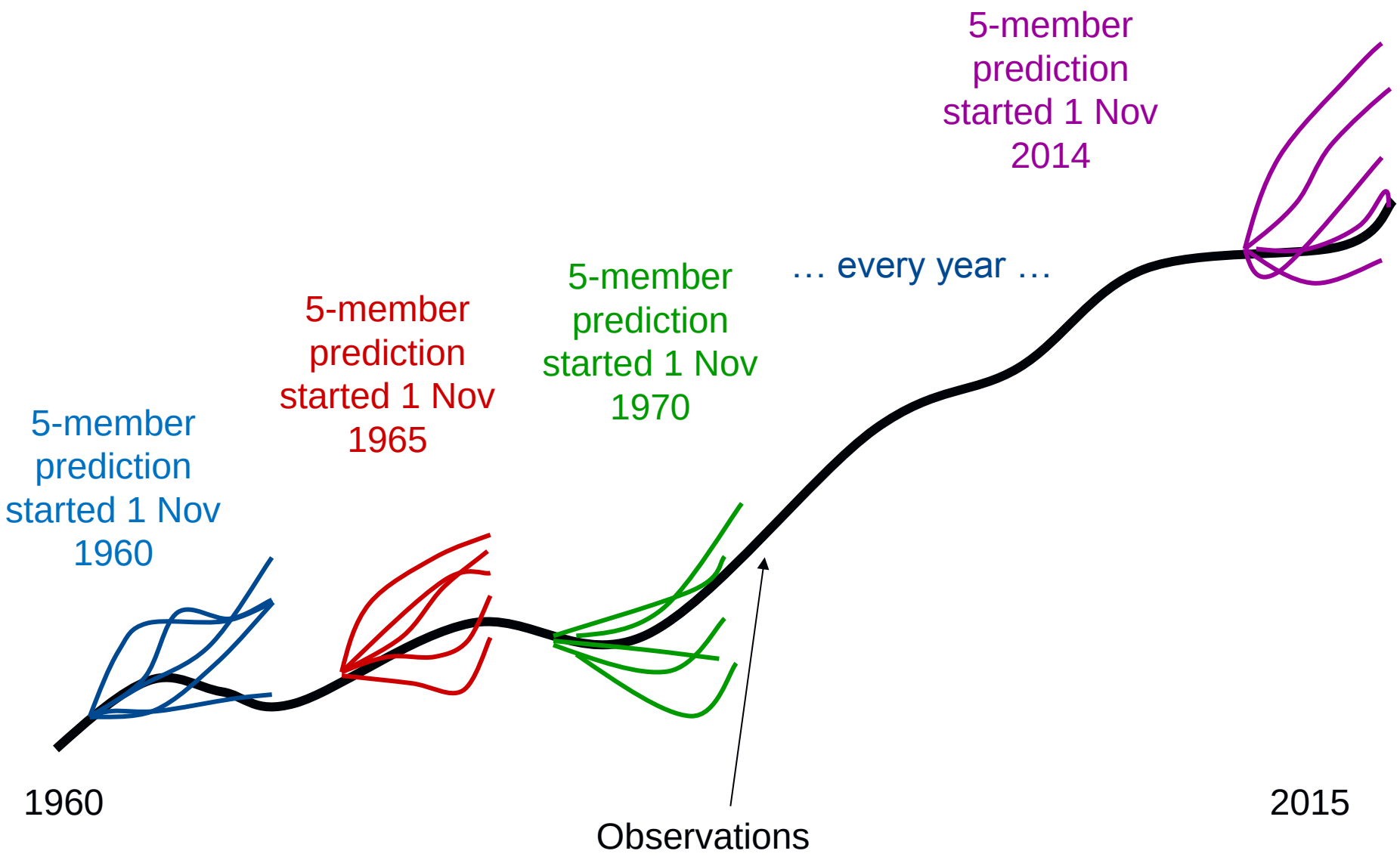
Climate predictions



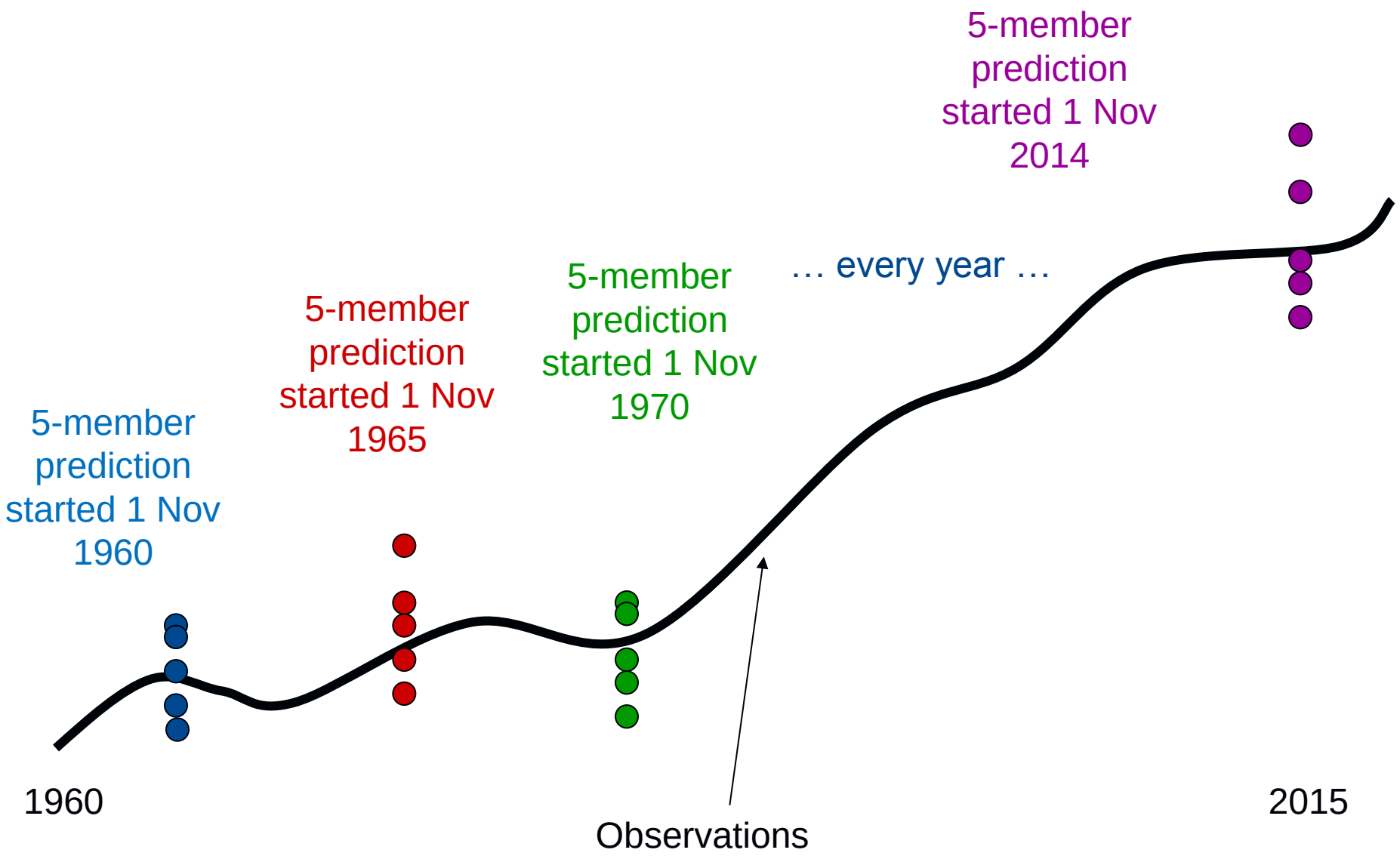
Climate predictions



Climate predictions



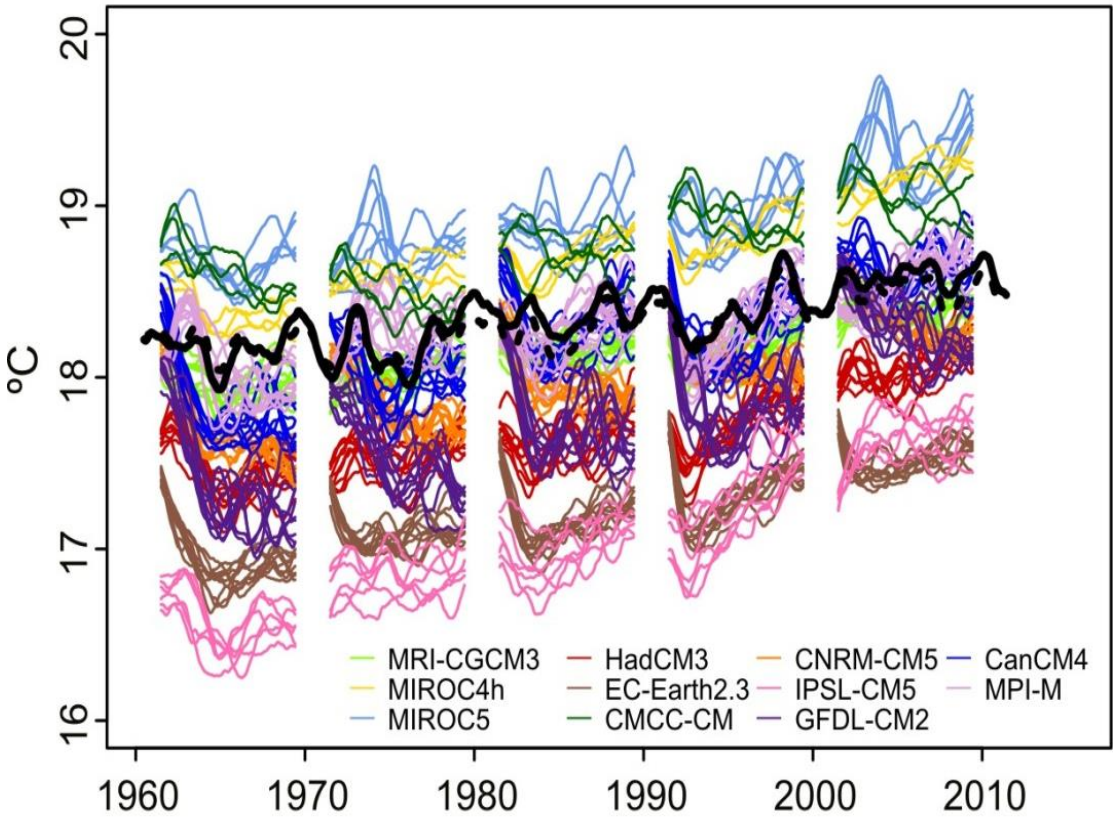
Climate predictions



Systematic errors in climate prediction

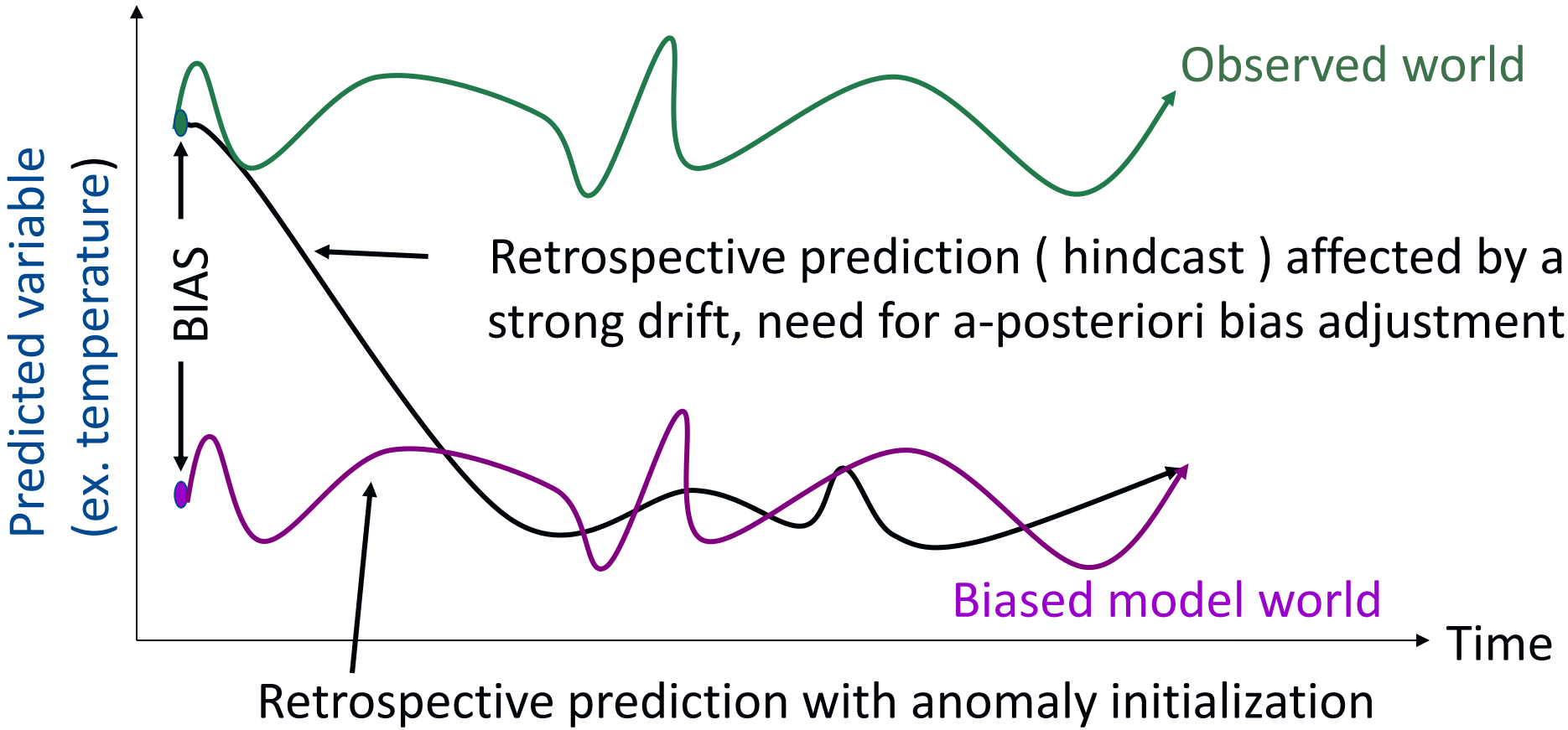
Global mean near-surface air temperature over the ocean (one-year running mean applied) from CMIP5 hindcasts. Each system is shown with a different colour. NCEP and ERA40/Int used as reference.

Shock and drift is the norm (mainly in full-field initialisation).



IPCC AR5 WGI (2013)

The climate prediction drift issue



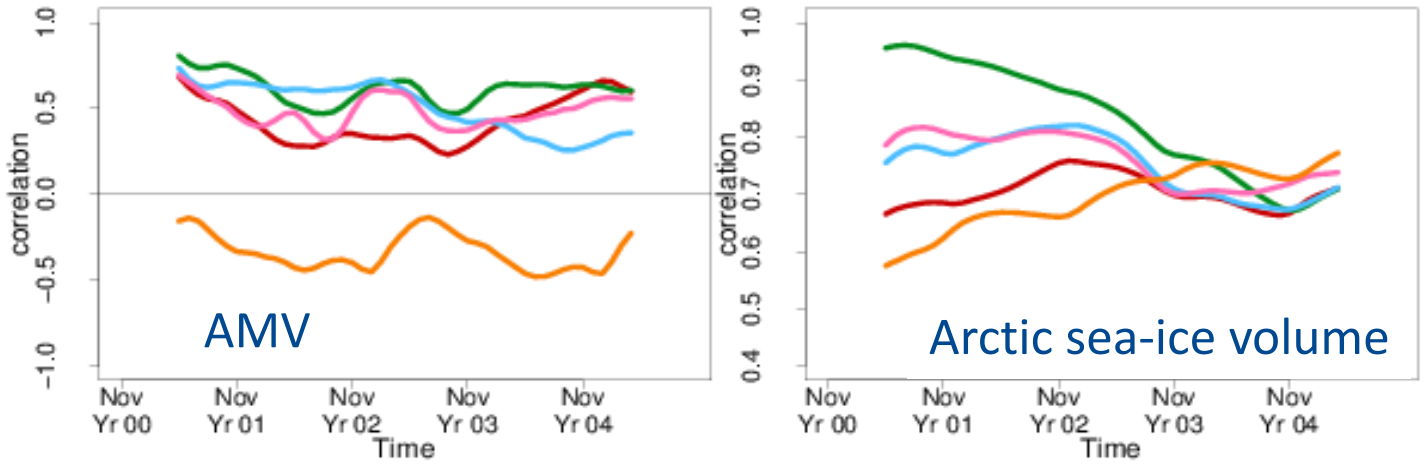
Initialization approaches

Assessment of full-field and different flavours of anomaly initialisation.

Full fiel (red), anomaly in the ocean (blue), weighted anomaly initialisaton in the ocean and the sea ice, with correction of T and rho instead of the usual T and S (green), and a weighted anomaly nudging in the ocean (pink).

Decadal prediction experiments run with EC-Earth2.3. Comparison with historical ensemble simulation (orange). 5 ensemble members, one start date every 2 years.

Reference data: ERSST data for AMO and SST, sea-ice reconstruction from Guemas et al. (2013) for sea-ice area and volume.



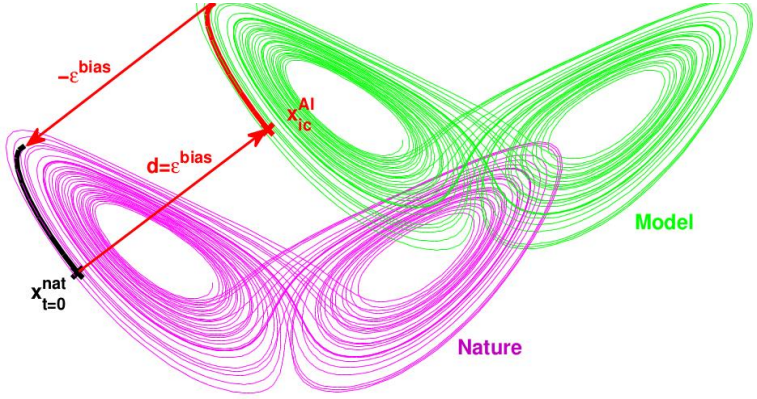
Volpi et al. (2015, Clim. Dyn.)

Initialization, back to simple models

Testing the relative merits of AI or FFI using a mapping scheme.

PDFs of initial conditions (black and red) and of the model and "nature" climatologies (blue and green) for the Peña and Kalnay model with three compartments (ocean, tropical atmosphere and extra-tropical atmosphere).

Mapping in anomaly initialisation

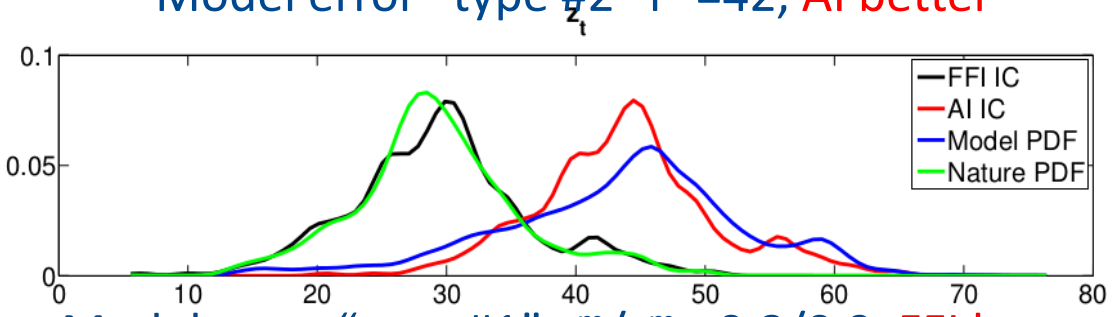


The prevailing initialization scheme corresponding to each model

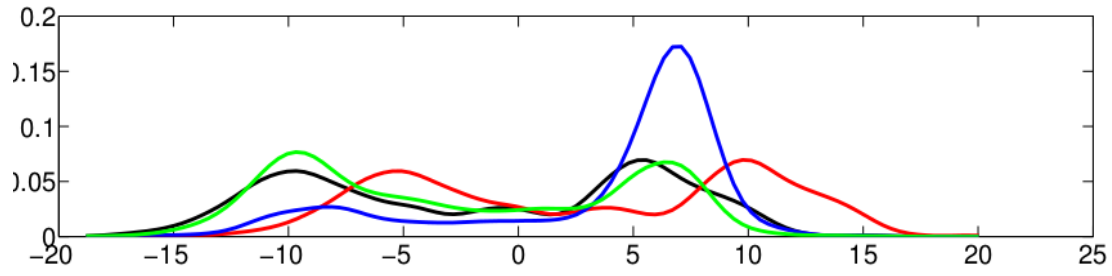
Model	Main PDF differences	Prevailing scheme
L63	Bias	AI
PK04	Bias	AI
PK04	Higher than first order	FFI
VD14	Higher than first order	FFI

From Peña and Kalnay model

Model error "type #2" r^m=42, AI better



Model error "type #1" c^m/c^m_z=0.8/0.9, FFI better



Carrassi et al. (2014, NPG), Weber et al. (2015, MWR)

Initial shock and drift workshop

- A workshop organised by the SPECS and PREFACE FP7 projects and sponsored by WGSIP will take place in Barcelona on 10-11 May 2016.
- The objective is to show the latest results on the sources and conditions of the initial shock and drift, to assess the impact on the forecast quality, and to organise some coordinated work taking advantage of the WGSIP initial shock and drift project.
- Sensitivity to the initialisation methodology (coupled initialisation) and product (GSOP) will be central.
- A discussion for recommendations for bias adjustment in CMIP6 will also take place.

CMIP6

- Decadal prediction will benefit from being part of CMIP6:
  - Better understanding (to, hopefully, reduce the drift) of the systematic error.
  - Control runs for predictability estimates.
  - Infrastructure: data dissemination, model documentation, diagnostics.
- Other MIPs could benefit from the decadal-prediction MIP:
  - Reduction of the systematic error by understanding the drift sources.
  - Continuous verification of the models.
- Decadal prediction will be a very expensive part of CMIP.
- Real-time decadal prediction exchange will continue and be enhanced (with more variables). Contribute to climate services and WCRP grand challenges.
- The impact of improving many processes still open: sea ice, volcanic and anthropogenic aerosols, vegetation and land…

Pre-CMIP6: Volcanic aerosol

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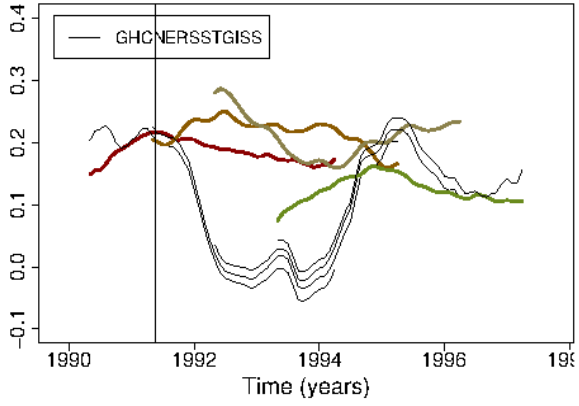
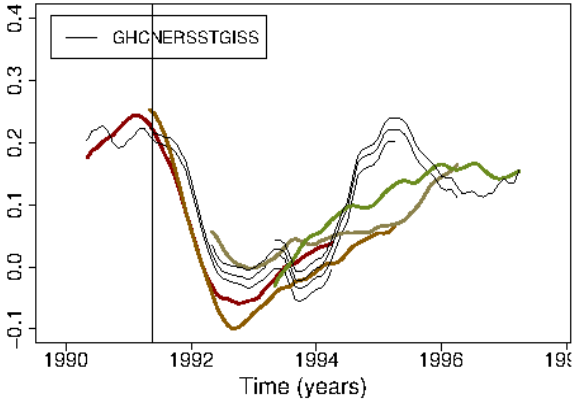
Collaboration with other MIPs (VolMIP).

Global-mean surface temperature before and after the Pinatubo eruption simulated by EC-Earth 2.3 with five-member ensemble hindcasts. Observational data is a mix between GHCN, ERSST and GISS.

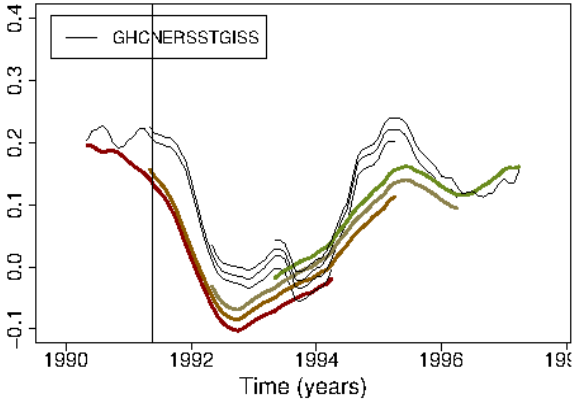
Both the initialisation and the volcanic forcing improve the simulations. But we can't predict volcanoes (either explosive or small succession), and even when they are off, we don't know the load distribution.



Initialisation and no volcanoes



Initialisation and volcanoes

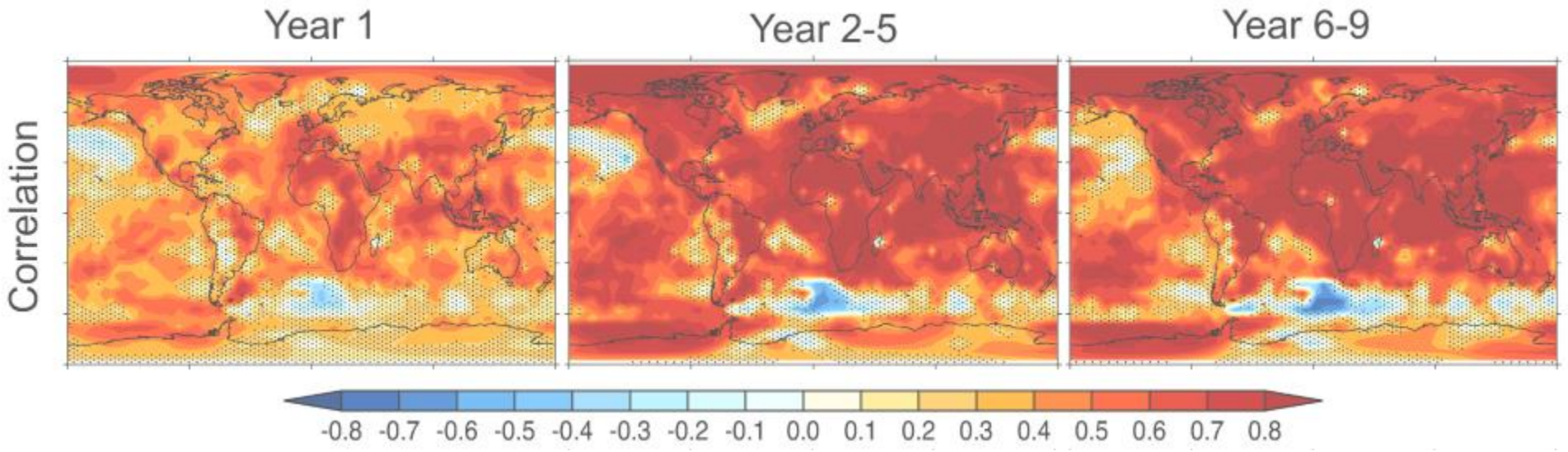


No initialisation and volcanoes

M. Ménégoz (IC3)

Pre-CMIP6: Benchmarks

A generalised empirical, ensemble-based decadal forecast system already exists. Should it be the (a) benchmark in CMIP6?

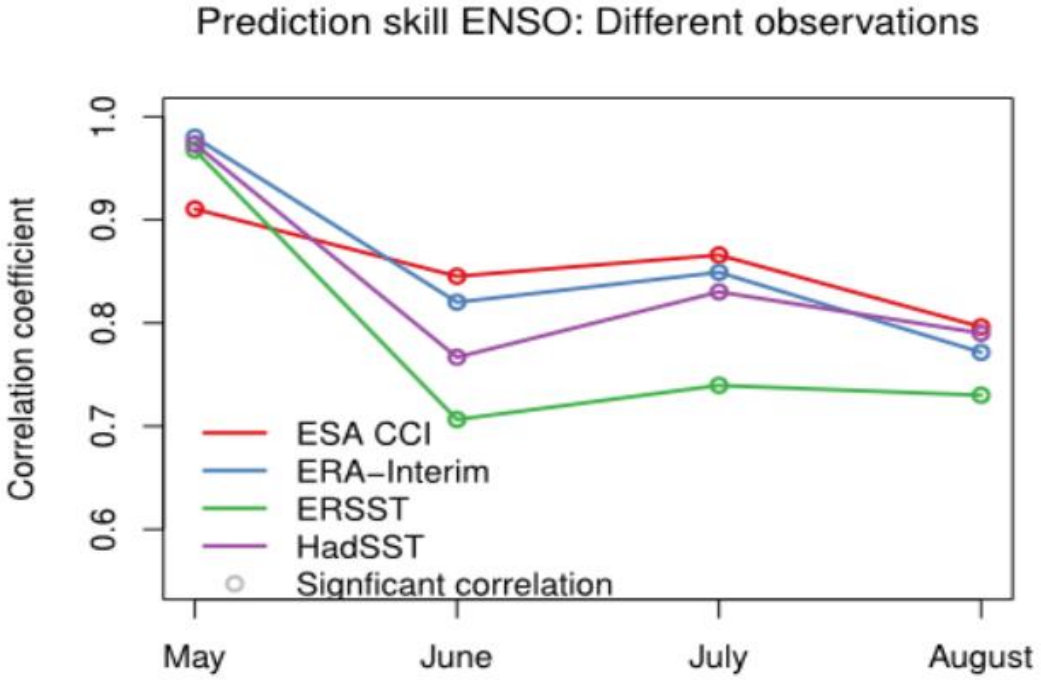


Suckling et al. (submitted)

GCOS/GSOP: Observational uncertainty

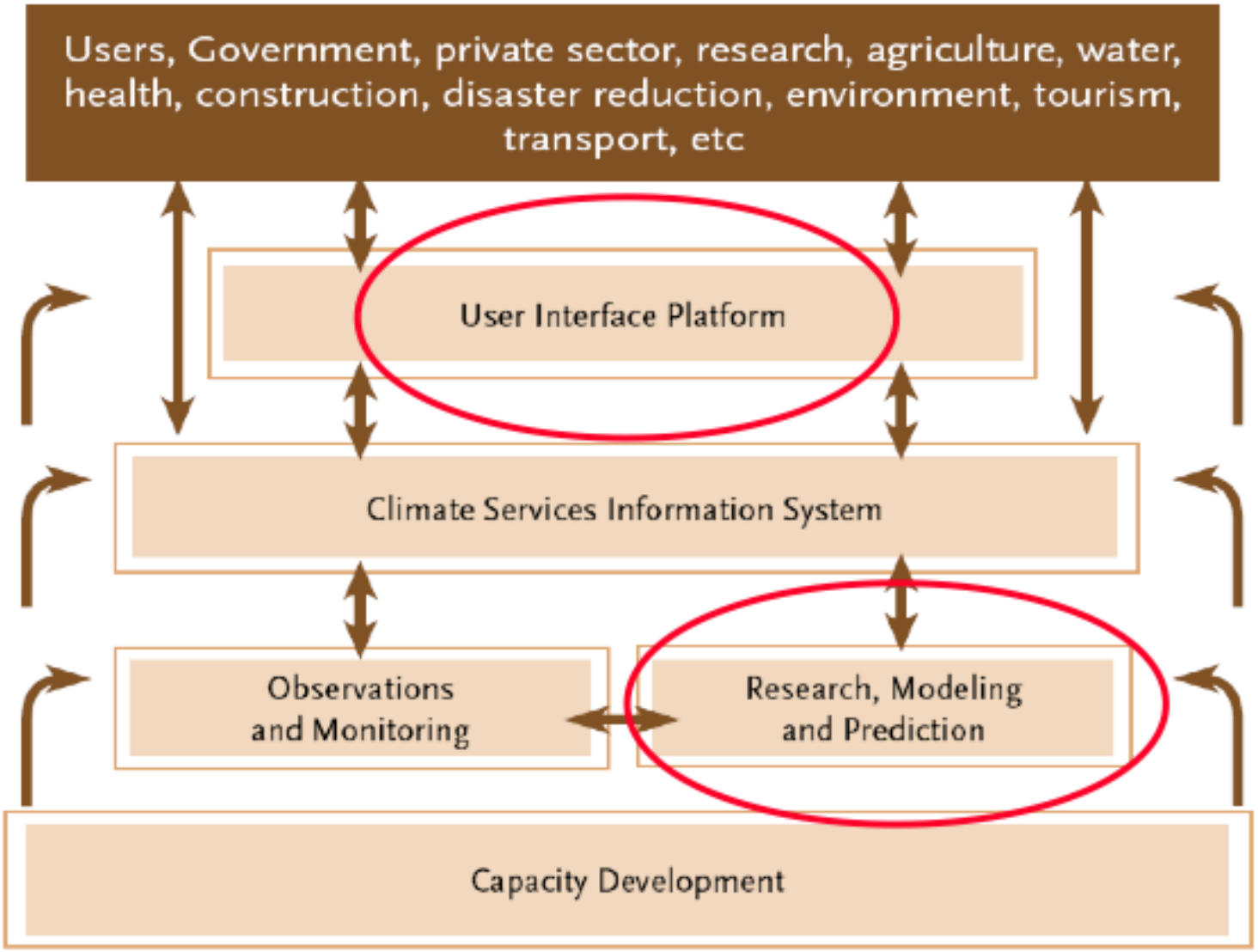
Need to take into account the large observational uncertainty both in the initialisation and the forecast quality. The Global Climate Observing System (GCOS) is a key actor in this task.

EC-Earth3(T511/ORCA025) predictions started every May over 1993-2009 with ERAInt and GLORYS2v1 ics. and internal sea-ice reconstruction.



Bellprat et al. (2015, IC3 Tech. Note)

GFCS


Users, Government, private sector, research, agriculture, water, health, construction, disaster reduction, environment, tourism, transport, etc
User Interface Platform
Climate Services Information System
Observations and Monitoring
Research, Modeling and Prediction
Capacity Development

Service-driven climate research

Ethical Framework for Climate Services four core elements: integrity, transparency, humility and collaboration.

WGSIP/DCPP: Prediction exchange

The multi-model real-time decadal prediction exchange is a research exercise that guarantees equal ownership to the contributors.

WMO-CCl will sponsor this activity.

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel

Multi-model decadal forecast exchange

The Met Office coordinates an informal exchange of near-real time decadal predictions. Many institutions around the world are developing decadal prediction capability and this informal exchange is intended to facilitate research and collaboration on the topic.

The contributing prediction systems are a mixture of dynamical and statistical methods. The prediction from each institute is shown below, alongside an average of all the models. When possible, observations for the period of the forecast are also shown. Currently three variables are included: surface air temperature, sea-level pressure and precipitation. These are shown as differences from the 1971-2000 baseline. More diagnostics, including ocean variables are planned for the future. Please use the drop-down menus below to explore the data collected to date.

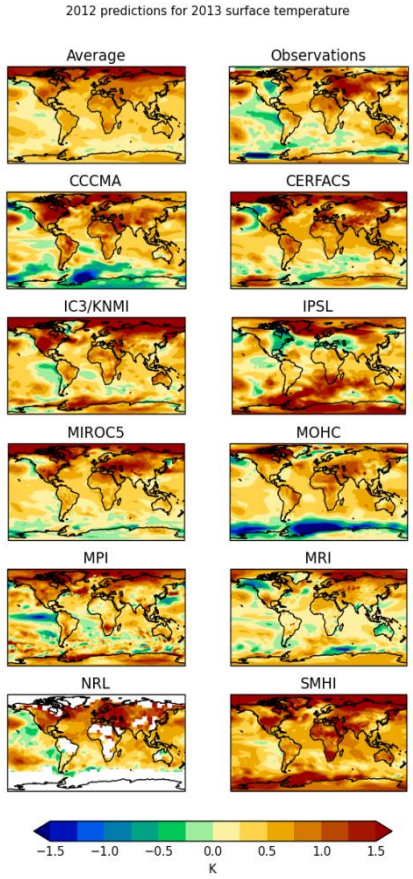
This work is supported by the European Commission SPECS project.

To learn more about decadal forecasts at the Met Office, see our current decadal forecast.

Images last updated 2014-06-25

Issued: 2013 | Period: year 1 | Element: surface air temperature

Decadal forecast exchange 2013 predictions for year 1 surface air temperature

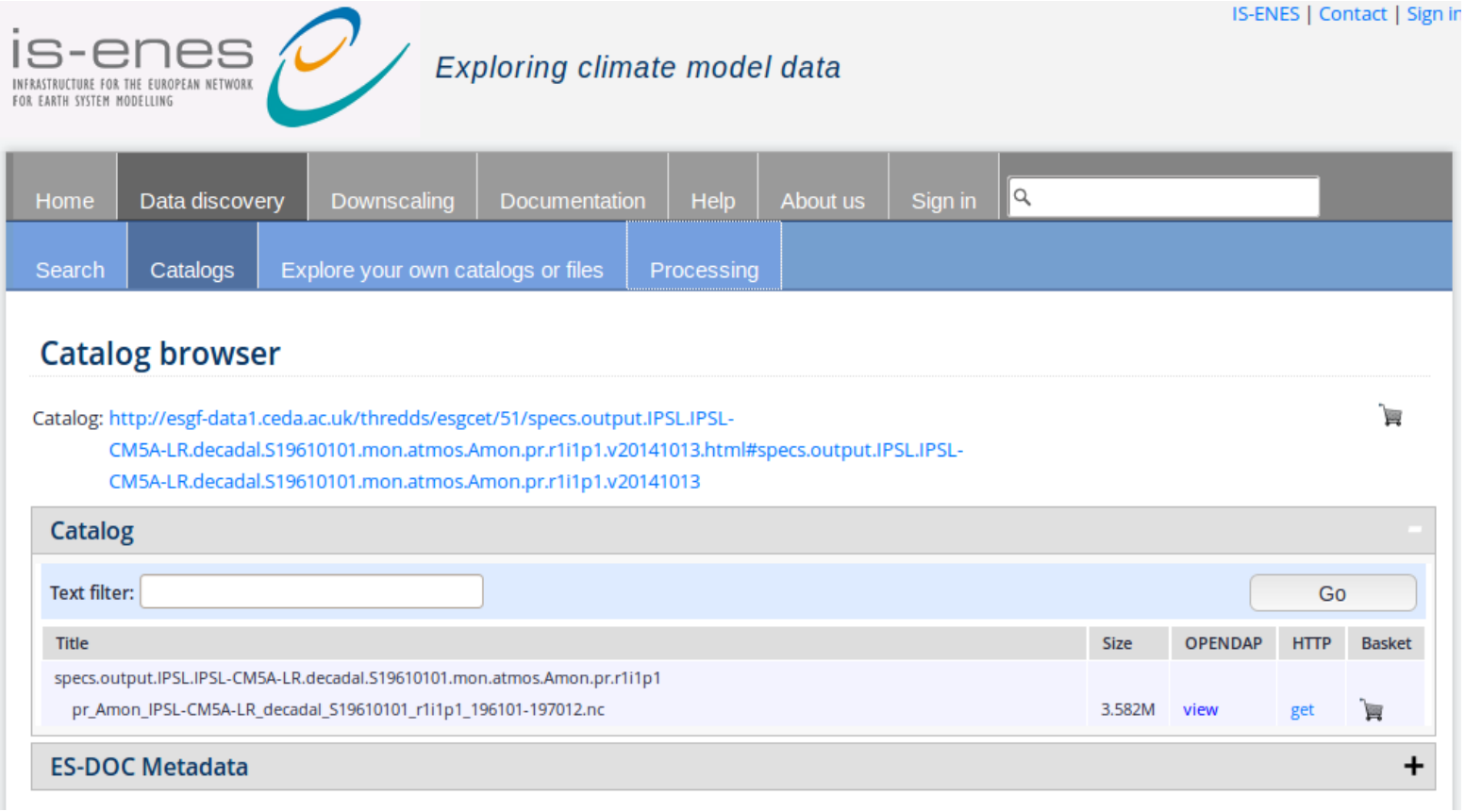


Downstream services

An example of downstream service: The SPECS data are now visible from the Climate4impact portal http://climate4impact.eu.

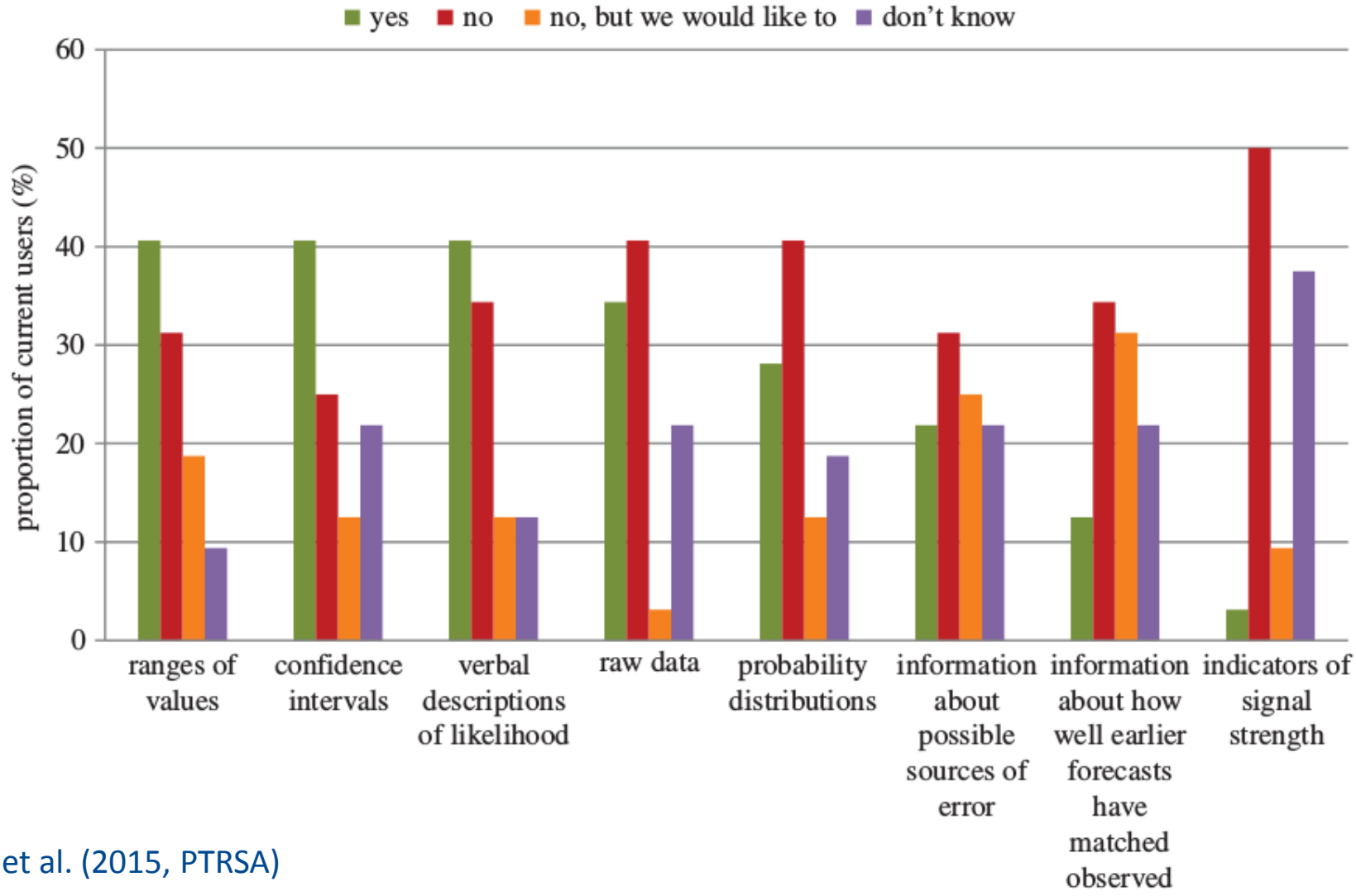
Lots of work still missing: e.g. use cases and processing demonstration video for climate predictions, etc

This is a key aspect for success, but...



Climate services research

Proportion of users of seasonal forecasts (n = 32) indicating whether they received different forms of information about uncertainty.



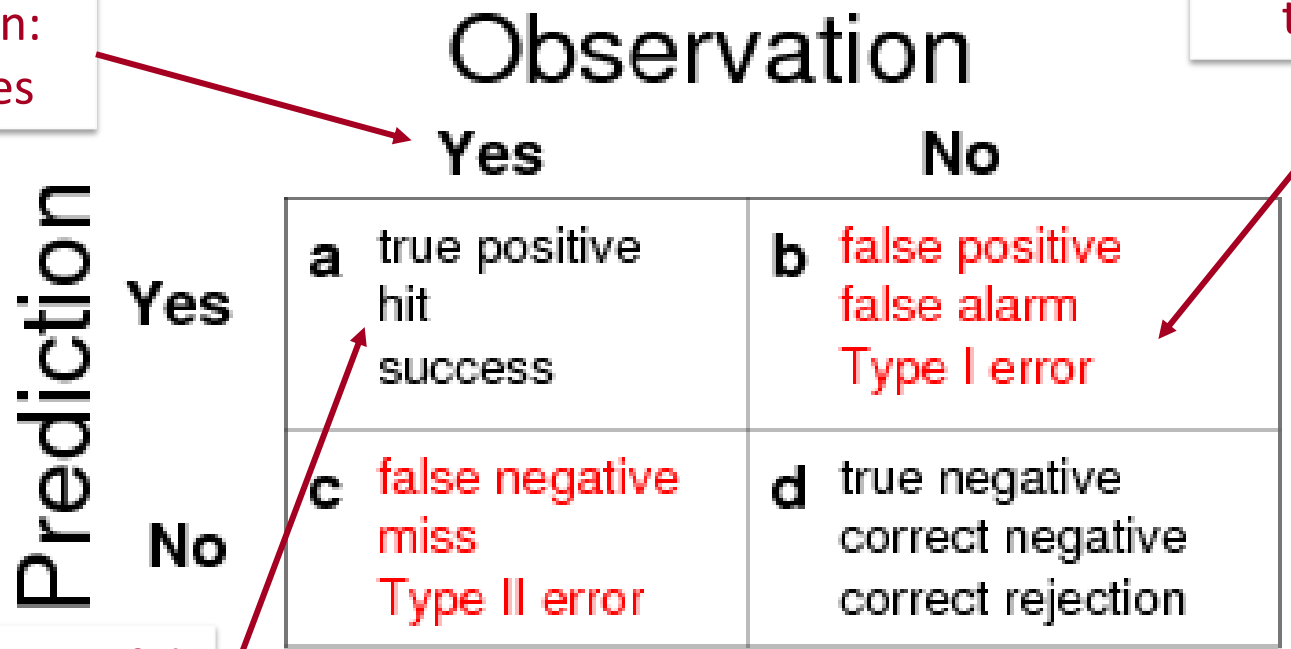
Taylor et al. (2015, PTRSA)

JWGFVR: The importance of verifying

- Joint WWRP/WGNE Working Group on Forecast Verification Research (JWGFVR).
- Huge source of forecast quality information, tools, training, etc.
- Verification only provides estimates, future skill might be either higher or lower.

This column: case studies

We never see this box



This box: beautiful successes

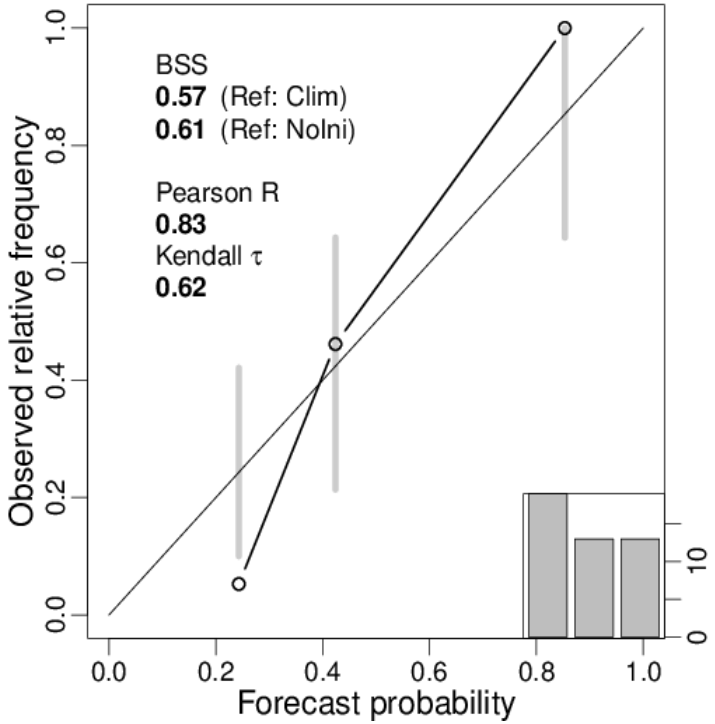
Interpreting reliability

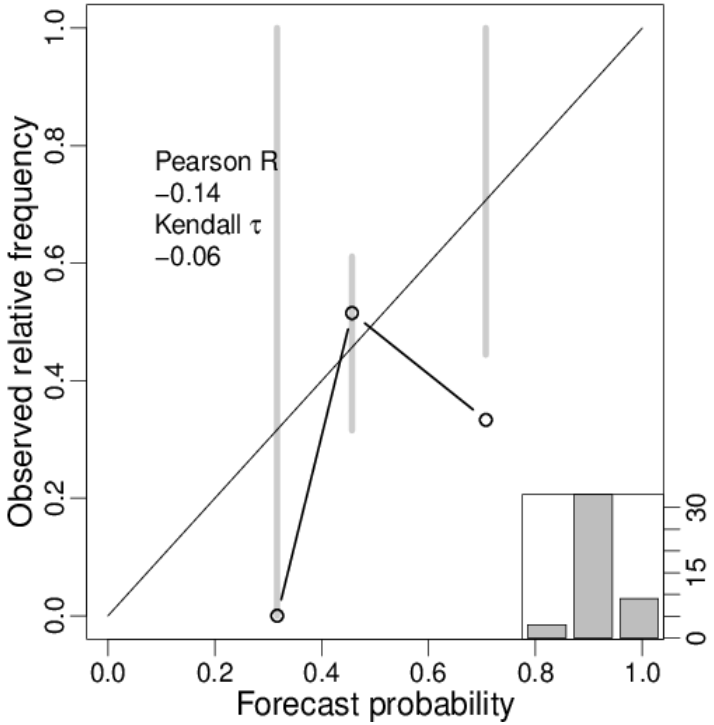
- Probability facilitates communication with the end user and allows better decisions.
- Reliability: if the probability of an event y is q the event should happen on average q 100% of the times $P(y=1|p=q)=q$.
- The reliability diagram is a plot of $P(y=1|p)$ over p. Pointwise consistency bars by resampling and histogram of probabilities (sharpness diagram) should be added.
- The rank histogram verifies the raw ensemble, independent from the method used to obtain the probabilities, and measures whether the ensemble and the observation come from the same underlying distribution. It requires exchangeability and would benefit from testing for alternatives to flatness.

Service-driven decadal predictions

Reliability diagrams of (left) initialised and (right) uninitialised MME simulations for basin-wide **accumulated cyclone energy** (ACE). The results are for 2-9 year averages above the climatological median over 1961-2009. Statistically significant values are in bold.

Some of the added value of the predictions is their better management of uncertainty, which leads to increased **credibility**.





Caron et al. (2015, GRL)

More on users: Deciding now

Bodegas Torres (a Spanish winery) is looking for new locations for its vineyards (and it's not the only one doing it).

Land is being purchased closer to the Pyrenees, at higher elevation. They are considering acquiring land in South America too, in areas where wine is currently not produced.

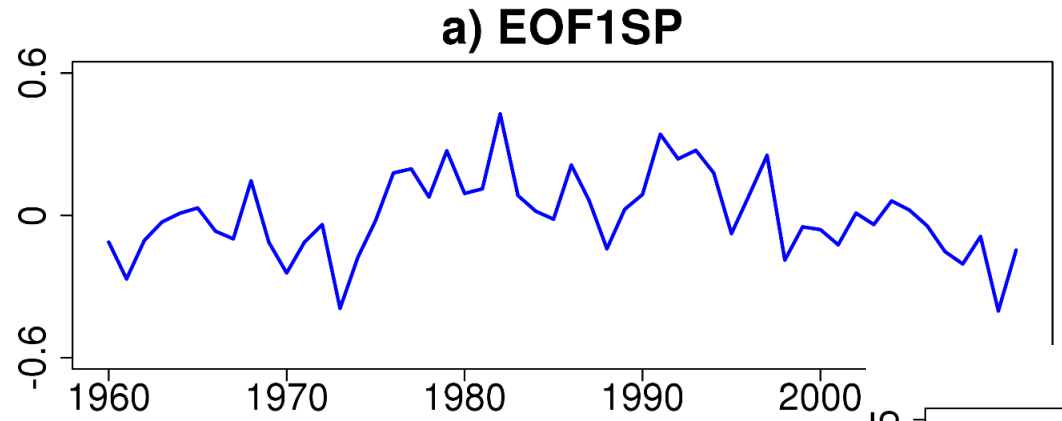
Bodegas Torres requests local climate information (including appropriate uncertainty assessments) for the vegetative cycle of the vine, which lasts 30-40 years.

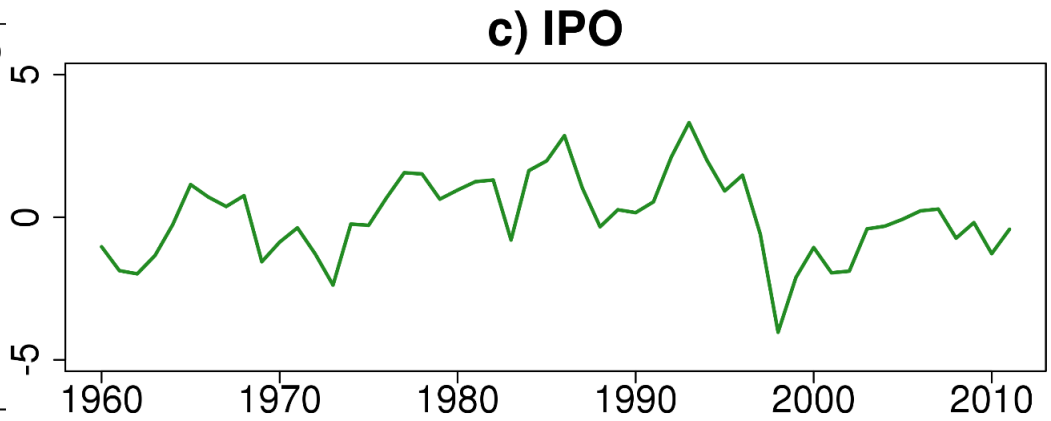
Some users need to make the decision now.

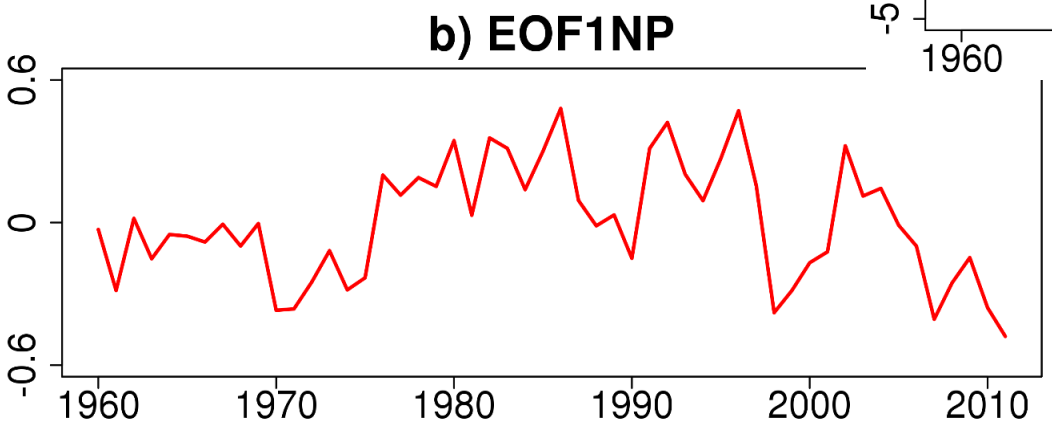
Climate services is a concept, predictions and projections are just a tool

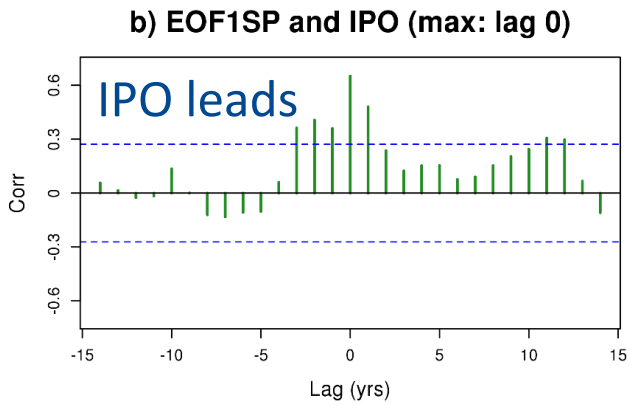
South Pacific predictions

Leading modes of SST in the South, North and pan-Pacific.







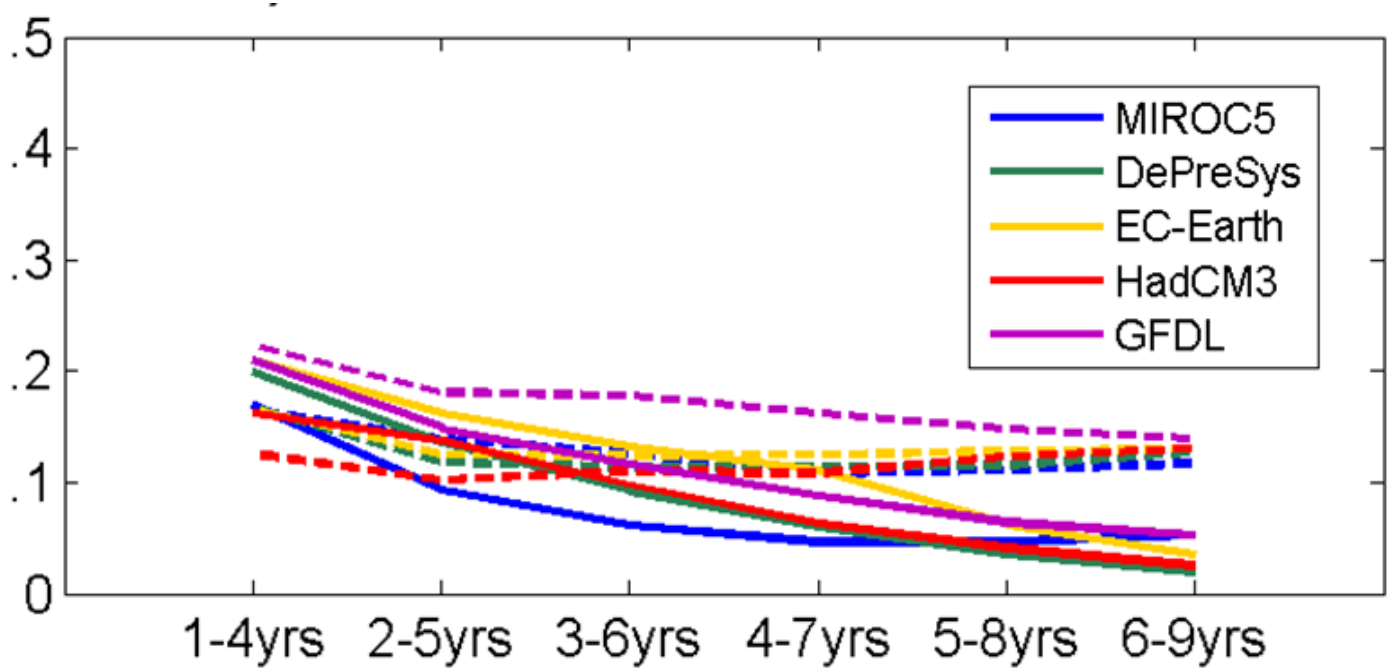


R. Saurral (UBA)

South Pacific predictions

Correlation of the ensemble mean of South Pacific decadal predictions.

Start date every year over 1960 to 2005 for the leading EOF of SST over the South Pacific (20ºS-65ºS). Solid lines for simulations initialized in extreme phases of ENSO and dashed lines for those initialized in neutral phases.



R. Saurral (UBA)

Deciding now

Response (anomalies with respect to 1986-2005) to Bodegas Torres from the RCP8.5 CMIP5 simulations for 2031-2050.

Indicador vitivinícola	*Lago Verde*	*La Tapera*	*Ñirehuao*	*Coyhaique*
Temperatura media anual	1.03°C	1.03°C	1.05°C	1.03°C
Temperatura media oct-abr.	1.16°C	1.14°C	1.14°C	1.10°C
Índice de Winkler	75.6°C	77.3°C	59.3°C	44.5°C
Winter severity index	0.85°C	0.86°C	0.96°C	0.97°C
Precipitación total anual	-114 mm	-109 mm	-85 mm	-96 mm
Precipitación oct-abr	-95 mm	-93 mm	-71 mm	-79 mm

Reaching out

A series of fact sheets started by the SPECS project (http://www.specs-fp7.eu) using a common vocabulary with the EUPORIAS project.

Targeting a wide audience, mimicking some material already existing to explain what climate change is.

SPECS Fact sheet #2

What is a decadal prediction?

October 2014

Weather is chaotic which limits its predictability to one or two weeks This means that it will never be possible to extend normal weather forecasts to seasonal time-scales and beyond.

For example, we will never be able to predict the weather on a specific date in a specific place years in advance. However, **changes in *prevailing* weather over the course of several months to years are potentially predictable**. For instance we may be able to say if a particular region might expect, on average, colder winters or drier summers. Such changes in weather patterns occur due to the interaction of the atmosphere with more slowly varying parts of the Earth system.

Weather is a result of energy moving through the Earth system. Energy is originally radiated to the Earth from the Sun, with most being re-emitted or reflected back to space. The amount that remains in the Earth system is modulated by many things: some emerge naturally within the system (*internal variability*), whilst others are controlled by external factors such as variations in solar output, greenhouse gases, and atmospheric particles

Summary

- There is a complex ecosystem of international initiatives relevant to decadal predictability and prediction.
- Requests for climate information for the next 30 years comes from a broadening range of users and should be addressed from a climate services perspective. What forecasters provide is still far from what some users demand (even in the absence of skill) and is only part of a complex story.
- Decadal prediction shows signs of providing useful information for some regions and events. Merging all this information into a reliable, unique source is a problem still not solved.
- Models still have substantial errors that need to be understood and communicated and have to deal with a substantial drift.
- None of this will materialize without appropriate investment in observational networks , increased collaboration and reduction of all aspects of model error.